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TITLE: A PERCEPTION OF GRAPHIC SYSTEM DATA BASE PROBLEMS AND NEEDS FROM A NUMERICAL CONTROL PROGRAMMER'S VIEWPOINT

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A PERCEPTION OF GRAPHIC SYSTEM DATA BASE PROBLEMS AND NEEDS FROM A NUMERICAL CONTROL PROGRAMMER'S VIEWPOINT

by

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The traditional two-dimensional engineering drawing as a means of communicating manufacturing data was all that was available until computers arrived. Engineering and design first used the computer as an analysis aid and as a means of calculating spatial relationships between assembly components.

Major computer programs for manufacturing piece parts appeared in the mid 50s. This marked the first time that engineering drawings were augmented by computer programs that could be used to run special machine tools. Thus computers began to be used to define, store, and use what has come to be known as manufacturing data bases. The special machine tools became known as numerically controlled (N/C) machines. These machines could be commanded through computer-assisted programs to manufacture shapes that were impossible to make conventionally. These shapes included conic and free-form curves and mathematically modeled surfaces. Engineering drawings were less and less able to depict the required shapes.

The computer and its related data bases began to increase designing and manufacturing capability, but the engineering drawing remained as the primary medium of communication between design and manufacturing. Manufacturing capability, after being relatively static for a number of years, moved toward increasingly sophisticated procedures that are still ongoing today.

Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) and integrated Graphics Systems (IGS) first appeared in the early 70s. In the beginning, these systems were used as an aid to engineering and design and were constrained to a two-dimensional representation of piece parts. The N/C machining capability that was added to most of these systems was very rudimentary. One enormous benefit arrived with CAD/CAM and IGS: Visibility. As these systems evolved, development of actual outlines of three-dimensional piece parts and the spatial relationship of one part to another became possible before the actual parts were manufactured.

Unfortunately, the two-dimensional engineering drawing remained as the communication medium between design and manufacturing. This drawing was transferred to the computer graphics screen, where it remains as the basis of the manufacturing data base. The verbal communication between designers and manufacturing people that served to clarify ambiguities and design intent tends to dry up since designers no longer have to physically carry engineering drawings to manufacturing. The designer stores his engineering drawing as a data base on the computer, and the manufactuirng people access this data base file and use it to develop N/C programs and manufacturing plans without verbal communication.

The ever-increasing sophistication and capability of manufacturing has exposed a need for more and more piece parts to be depicted in three dimensions. IGS is, in turn, becoming more capable of allowing this need. For many reasons, the two-dimensional engineering drawing has become woefully inadequate. Some of the problems the engineering drawing generates are: (See Figure 1)

A. It is ambiguous and open to misinterpretation.

B. It is usually geometrically inaccurate, even in the two-dimensional mode, because of tolerancing factors, arbitrary points of origin, lack of depth, and lack of associativity to other components in the same data base. (See Figure 2)

C. It is a two-dimensional representation of three dimensional requirements. (See Figure 3)

D. It becomes cluttered with supporting text that tends to blend into or hide geometry. (See Figure 4)

E. It is totally unsuitable for N/C work. This data must be altered and augmented to suit toolpath and safe machining practice requirements. (See Figure 5)

F. There is as high overhead cost to verify its accuracy.

G. Tolerances introduce lies to the data base, especially unilateral tolerances.

H. Communication problems between design and manufacturing arise because of diverse disciplines and varied skill levels working with the same data base.

The IGS of CAD/CAM has contributed problems also. Primary among these is the current state of the art for depicting piece parts. The pictures displayed are of feature outlines only. This is known as wire-frame construction. This environment is rather ambiguous and illusory, and contributes greatly to misinterpretation of the data depicted. Data tends to become "hidden" very quickly when one works in an IGS environment. The computer accepts the half truths and lies that we employ for depiction convenience. Eventually these fallacies are fed back as the truth. Errors built into

SOME PROBLEMS

- AMBIGUOUS
- GEOMETRICALLY INACCURATE
- TWO DIMENSIONAL
- CLUTTERED
- UNSUITABLE FOR N/C
- HIGH OVERHEAD
- TOLERANCES INTRODUCE LIES
- COMMUNICATION PROBLEMS

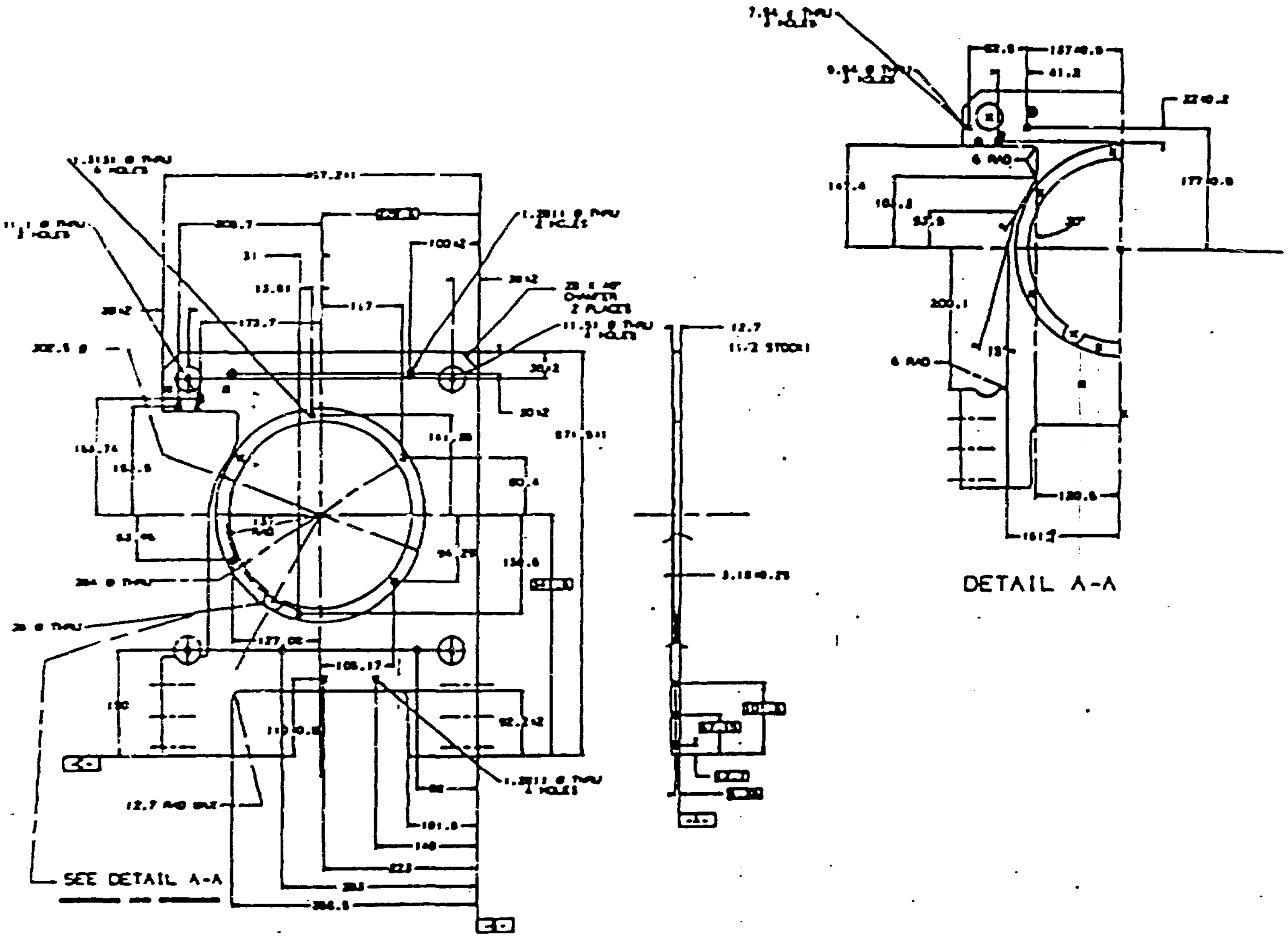
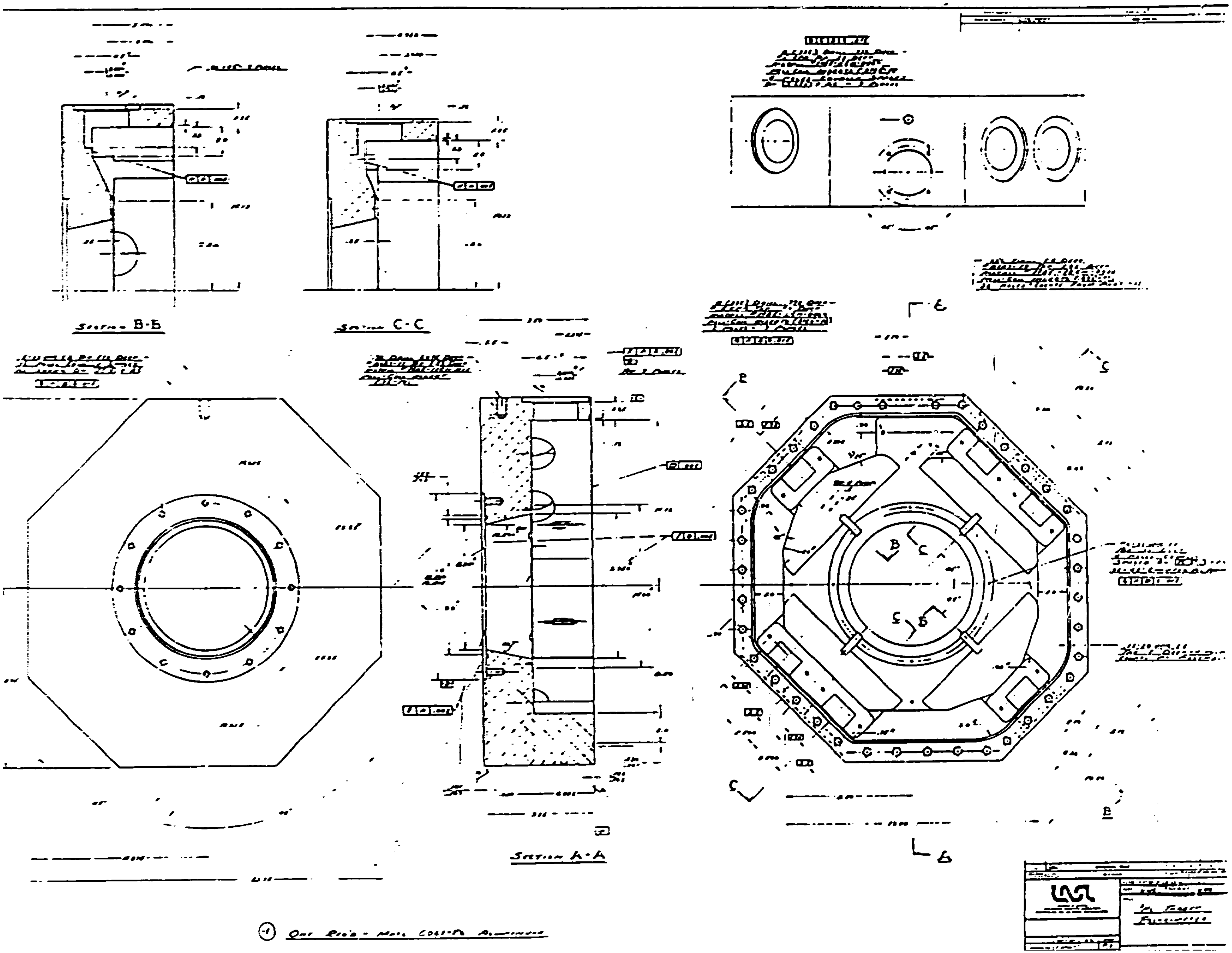


Figure 2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SECTION C-C
SECTION A-A

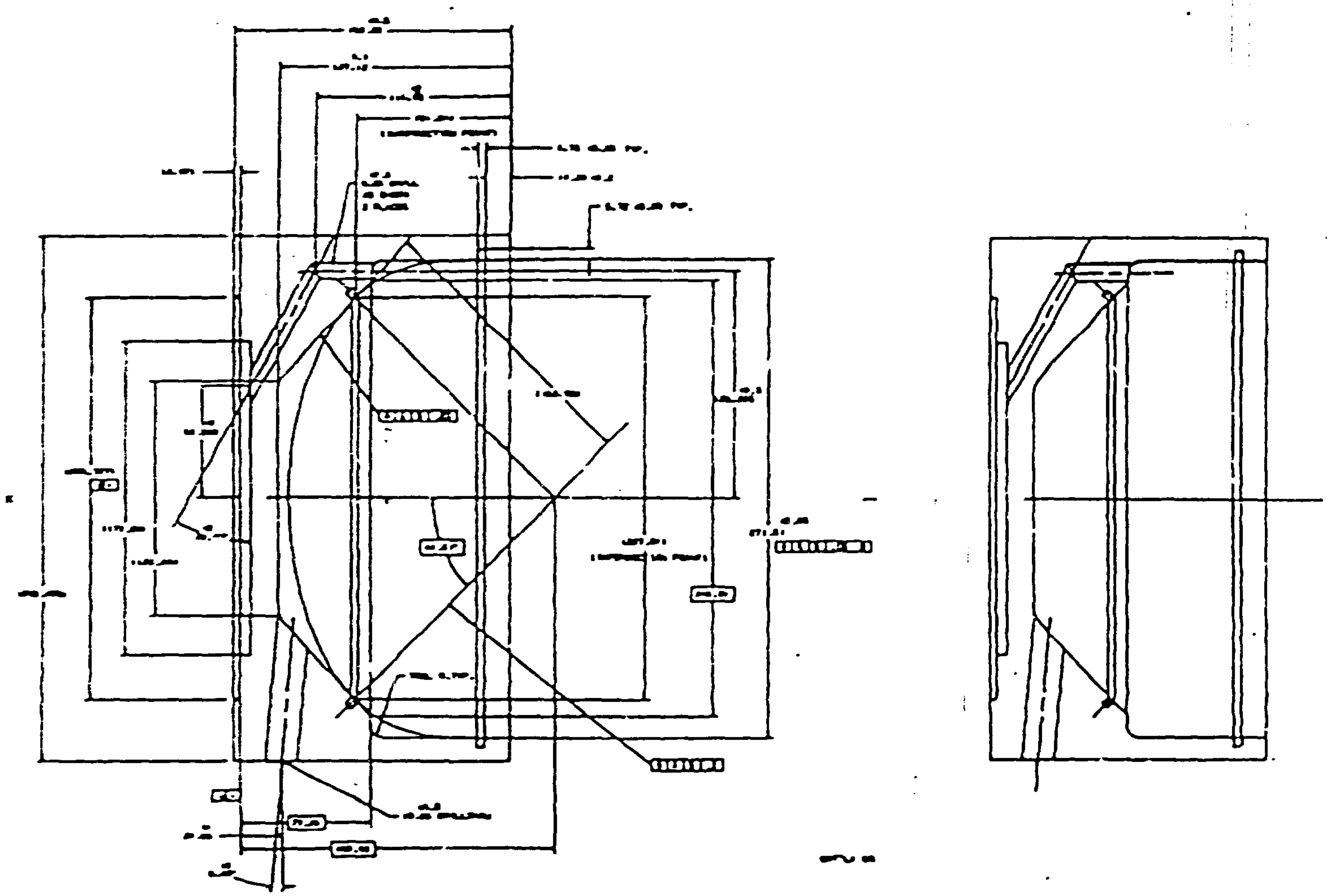


Figure 4

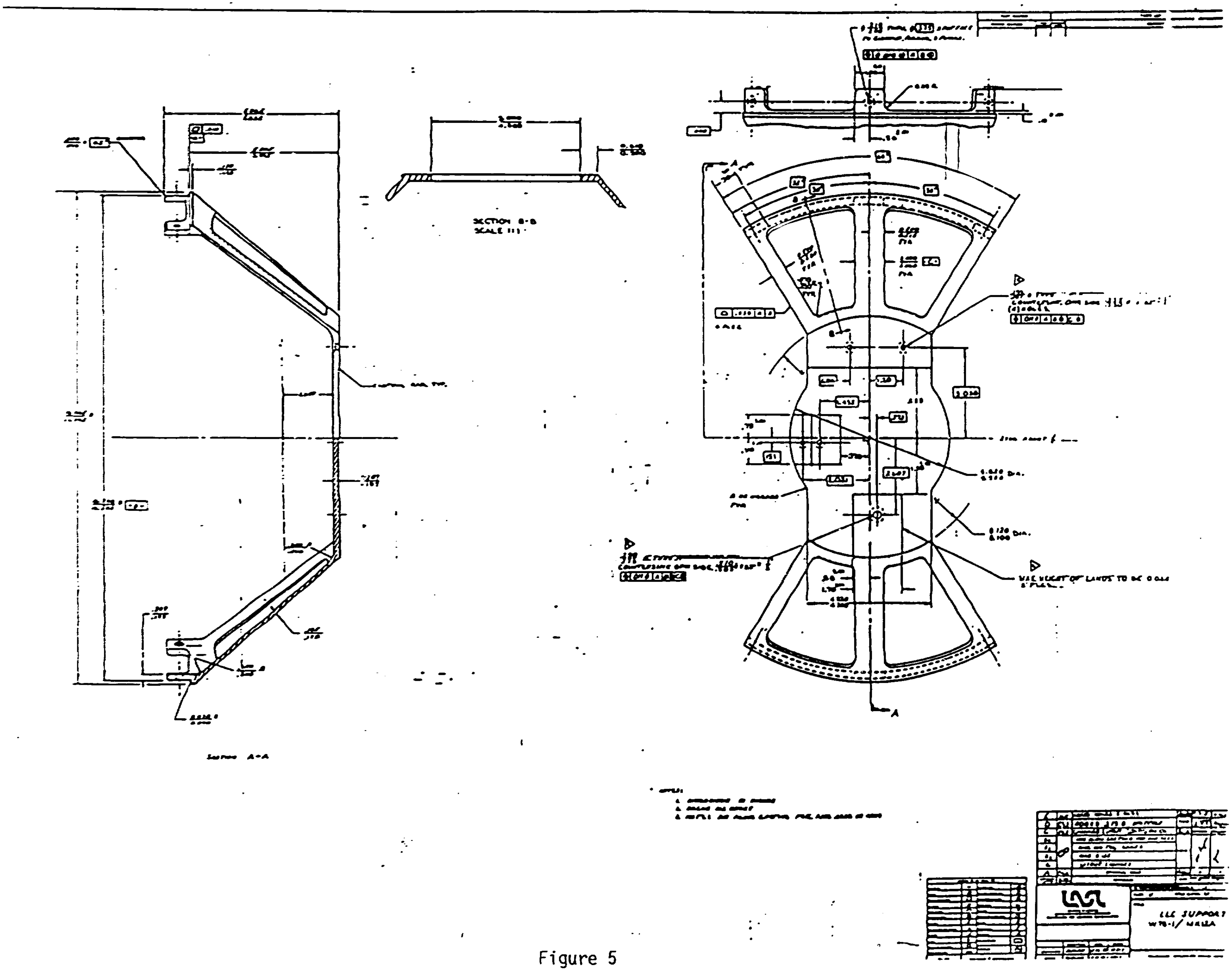


Figure 5

the data base in this manner tend to become surrounded by supportive data that hides the error until a critical time, usually at assembly or during a functional check. (See Figures 6 and 7)

The geometry as depicted in IGS is a boundary representation. This representation serves to tightly constrain the method of defining toolpaths for machining the part. Safe machining practice, tool-to-part orientation, and finish requirements dictate that the toolpaths start at a point removed from these boundaries and leave the boundaries at the end of a cutting sequence. Deviation from these constraints and supplementary commands must be added to the raw toolpath data manually through editing. Editing is usually an awkward and time-consuming task because of the limited capability of almost all CAD/CAM systems.

A geometric data base is insufficient for piece part definition, which causes problems. A dimensional data base that describes finishes, tolerances, welding requirements, and other symbolic and textual data is required. (See Figure 8)

More and more application packages that help define machinability requirements, process plans, efficient routing of a piece part through the machine shop, and other data are being added to CAD/CAM systems. Each of these require software interfaces. These interfaces snowball as application packages are added to the system. Additional skills are required of operators to access and use the application packages they desire. (See Figure 9)

Machining accuracy is becoming more and more necessary for a number of reasons: A need for nine significant digits of accuracy has become almost commonplace in the DOE community. Most CAD/CAM systems on the market today cannot meet these accuracy criteria. The only CAD/CAM systems that are able to supply this accuracy are either based on main-frame computers or incorporate double precision capability on a routine basis. (See Figure 10)

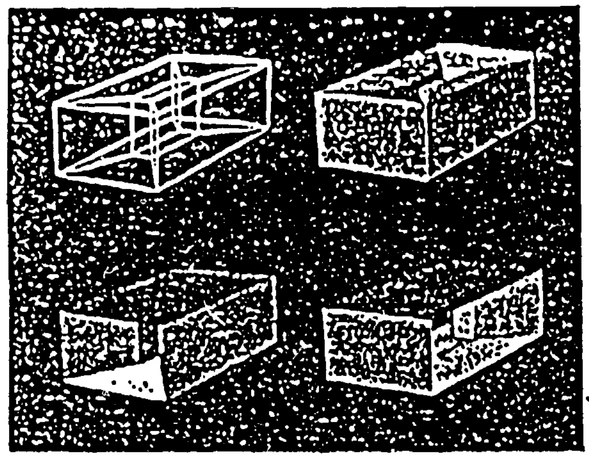
CAD/CAM systems are in a state of rapid evolution. Some of the needs that I have spelled out are already at hand, some are in the near future, and some are in the planning or experimental stage. The following summarizes a few of the needs that have to be addressed from a manufacturing viewpoint: (See Figure 11)

A. Data base definition rules should change. Three-dimensional data bases must be constructed when appropriate. (See Figures 12, 13, 14)

B. Concise dimensional, finishing, and other data must be supplied in textual or attribute form.

- "HIDDEN" ENTITIES
- OPTICAL ILLUSION
- BOUNDARY DRIVEN TOOLPATHS
- GEOMETRY DATABASE INSUFFICIENT
- APPLICATION PACKAGE COMPLEXITY
- LACK OF ACCURACY

Figure 6



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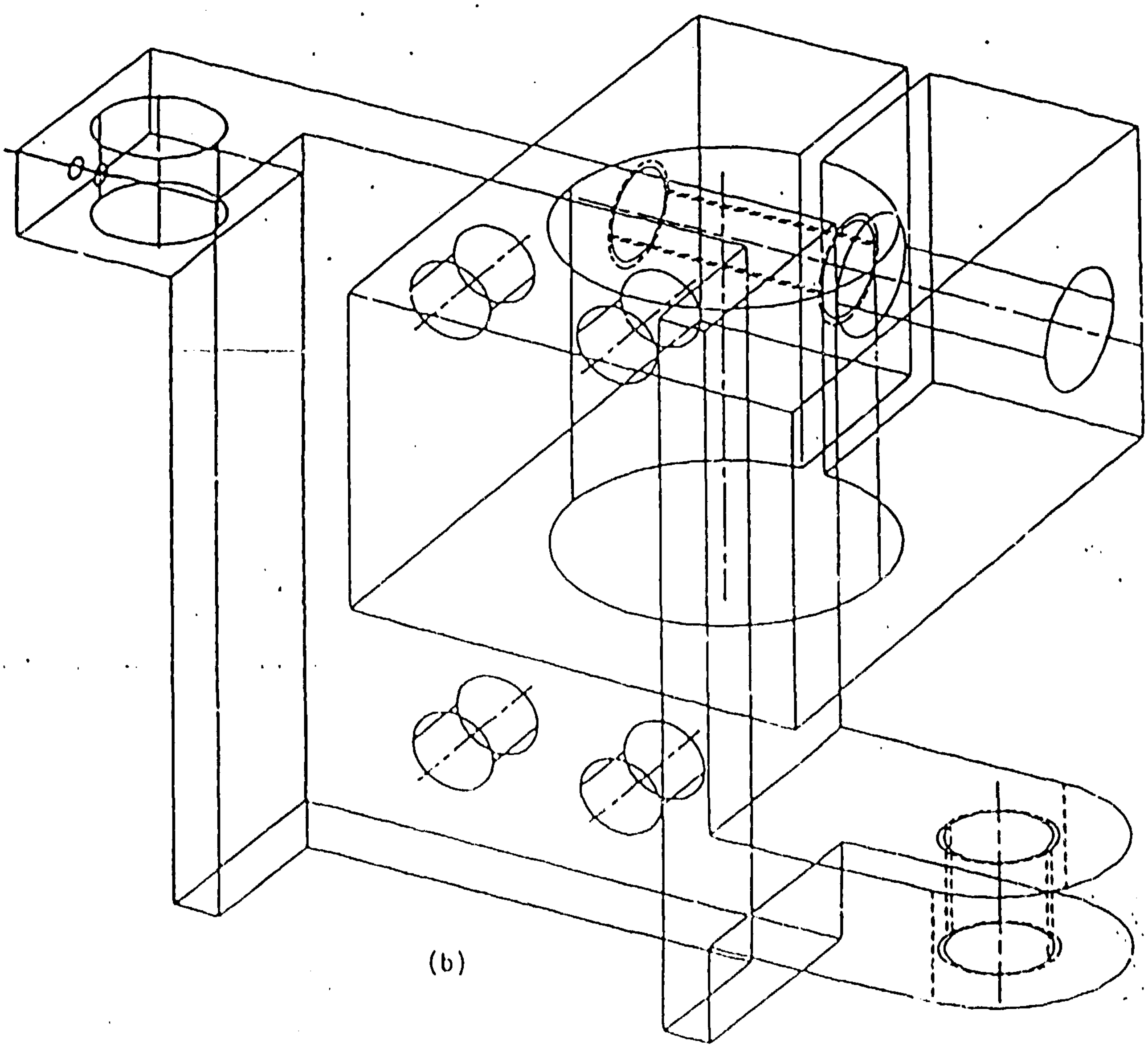

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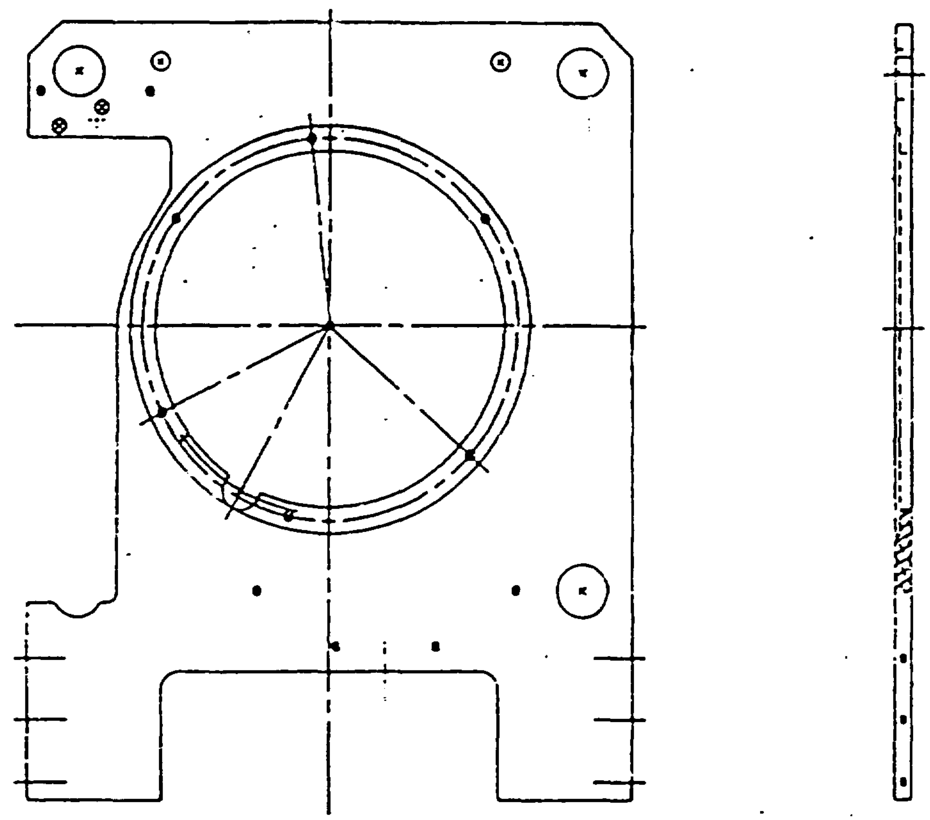

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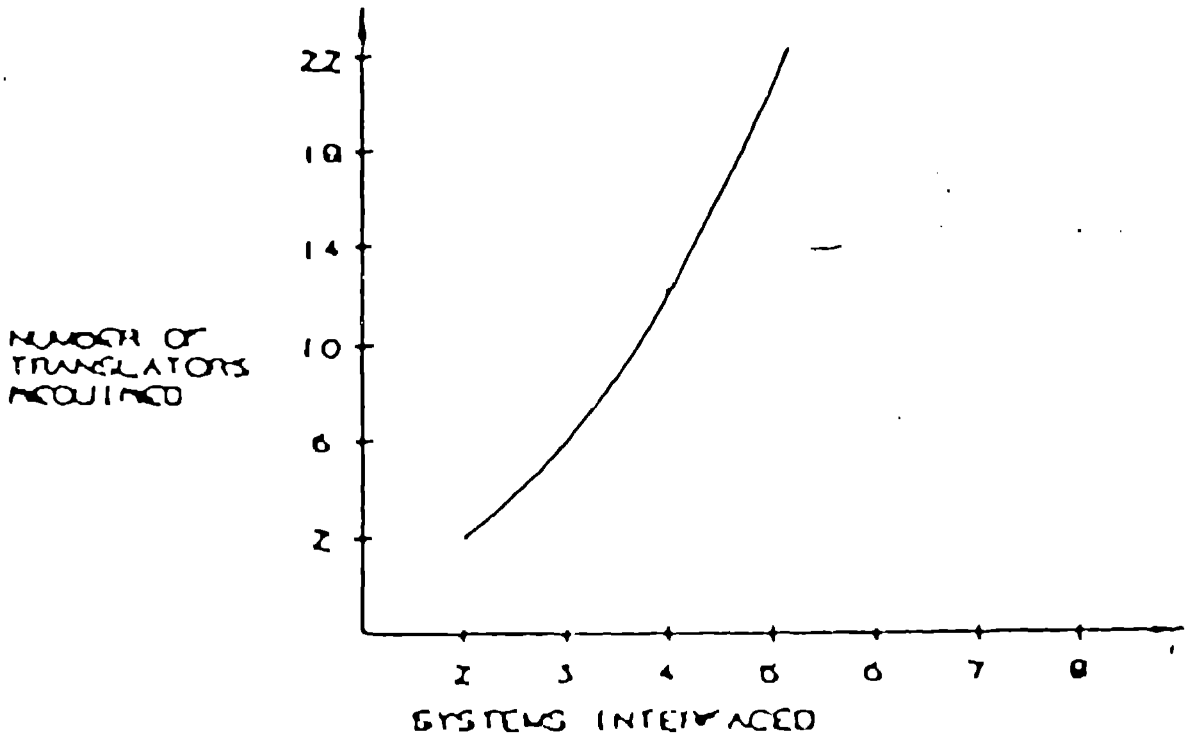
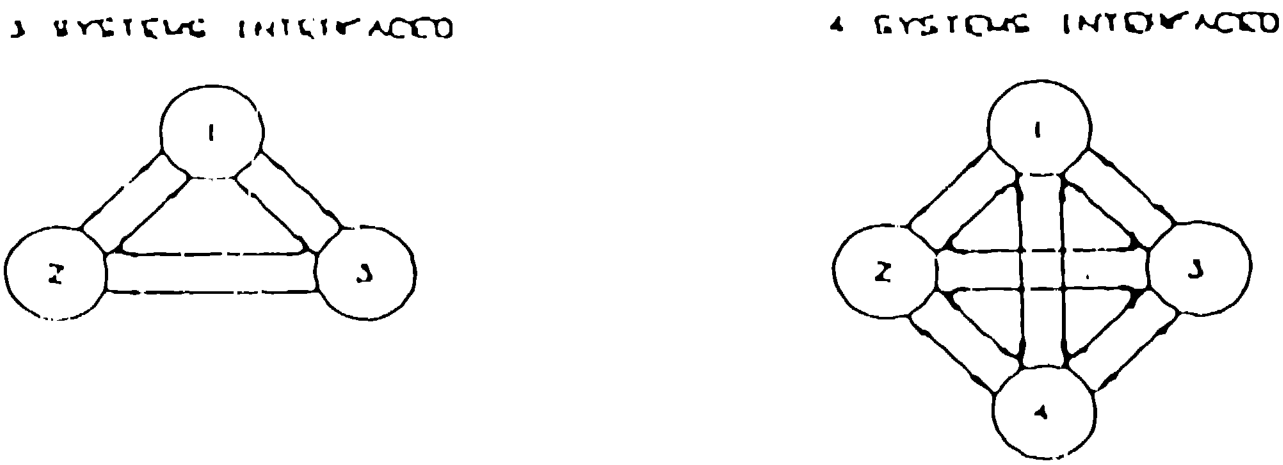
LEVEL 1: FRONT VIEW
LEVEL 2: SIDE VIEW
LEVEL 3: DETAIL MAGNIFICATION
LEVEL 4: DRAFTING, NOTES, TEXT, LEVEL TABLE
LEVEL 5: HOLES, POINTS, CENTER POINTS

Figure 8

DIRECT TRANSLATION





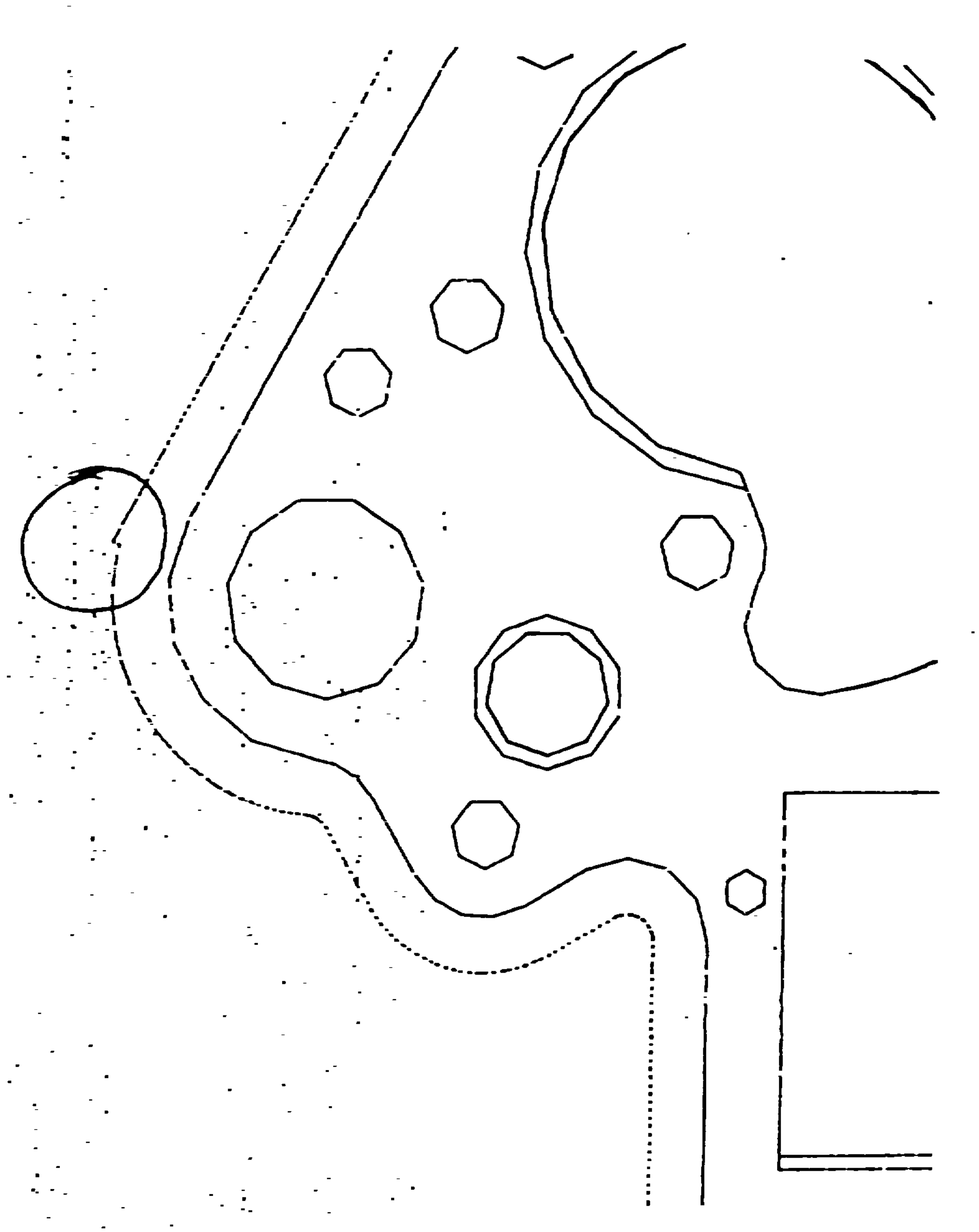
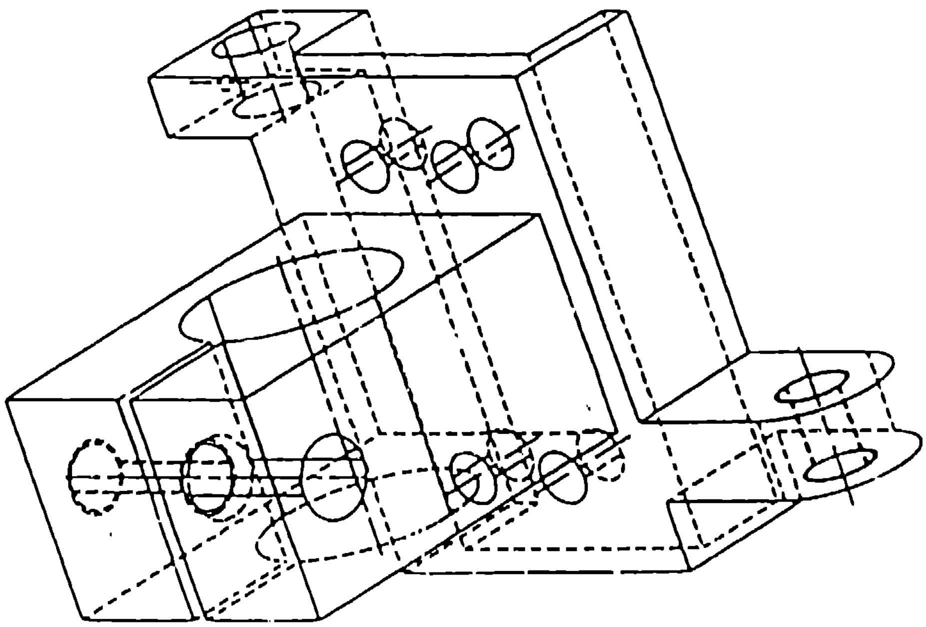


Figure 10

SOME NEEDS

- DATABASE DEFINITION RULES MUST CHANGE
- CONCISE DATA
- USABLE SOLID MODELING
- PROGRAMMABLE LANGUAGE SECTION CAPABLE OF ADDRESSING WHOLE DATA STRUCTURE

Figure 11



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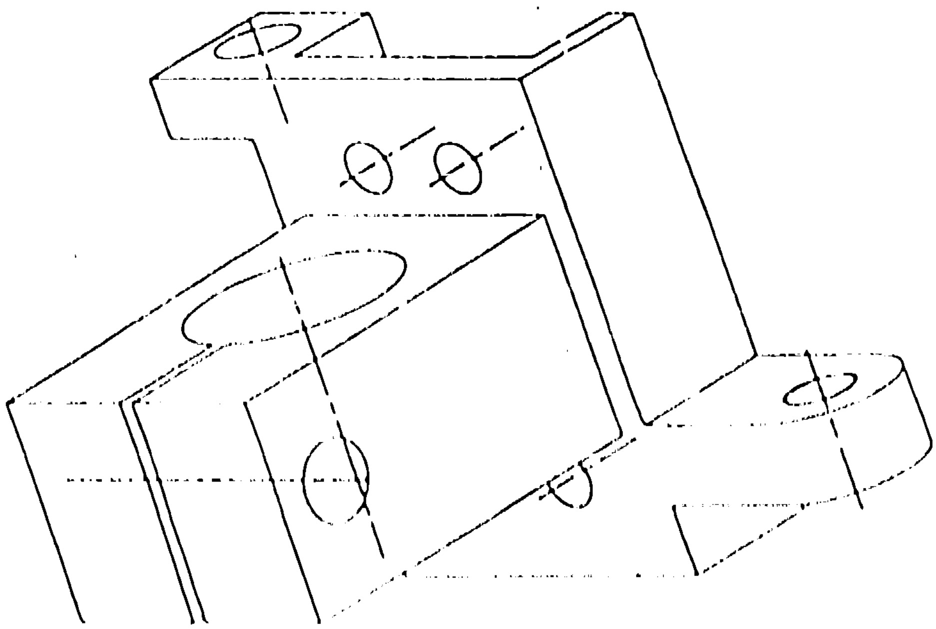


(b)

Figure 12

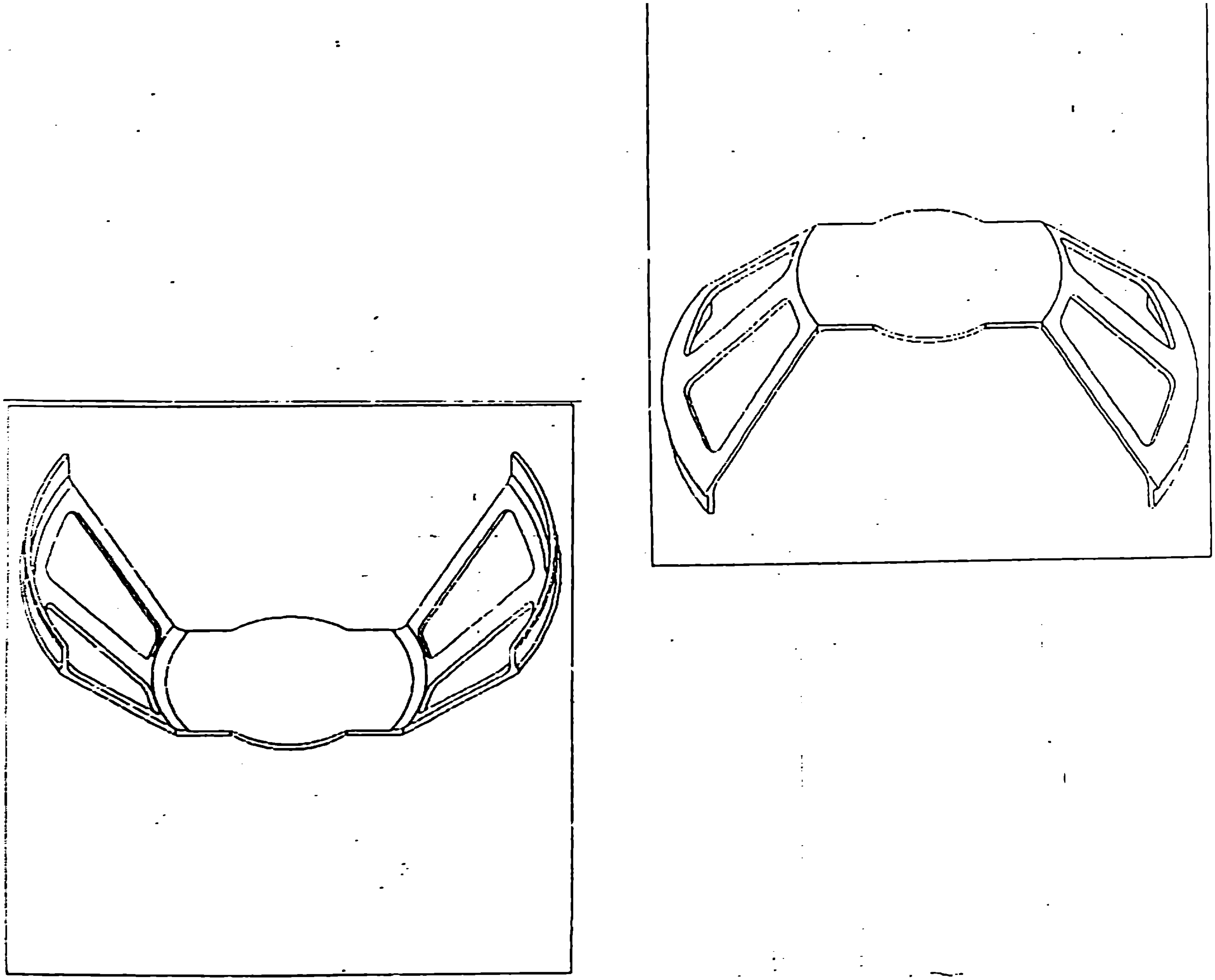
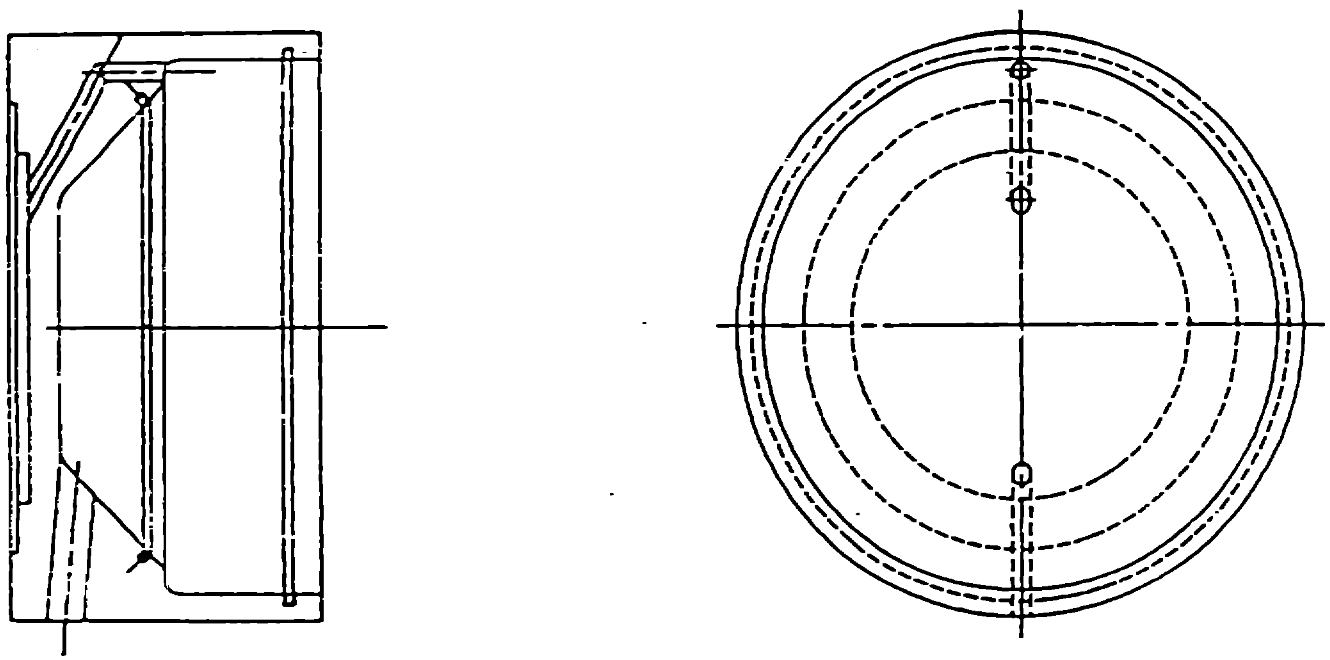


Figure 13



Fiqure 14

C. Usable solid modeling capability, when it becomes available, could prove to be a valuable definition tool.

D. Better toolpaths control, such as modification and regeneration capability, direction, insertion of data from other data bases (machinability, etc.). Better capability to mix point to point, continuous path, and godelta type movements in a toolpath. (See Figure 15)

E. Programmable language section of system capable of addressing the whole system data structure.

F. Broader N/C macro capability, including better handling of repetitive and/or similar toolpath requirements. Use of nonnumeric variable values, looping and subscripting capability.

Improved editing capability, such as synonym definition and usage; ability to search for and edit text and/or numeric strings; globally fix and manipulate strings, and other capabilities that will make toolpath editing more efficient than is currently available.

Although CAD/CAM is relatively new, it has proven itself to be a vehicle that lends itself to further exploration in productivity improvement. CAD/CAM capability is expanding at a phenomenal rate toward what could be an integral part of a revolution in manufacturing technology. (See Figure 16)

- BETTER CONTROL OF TOOLPATHS
- BROADER N/C MACRO DEFINITION
- IMPROVED EDITING

Figure 15

TESTED PRODUCT DEFINITION MODELS

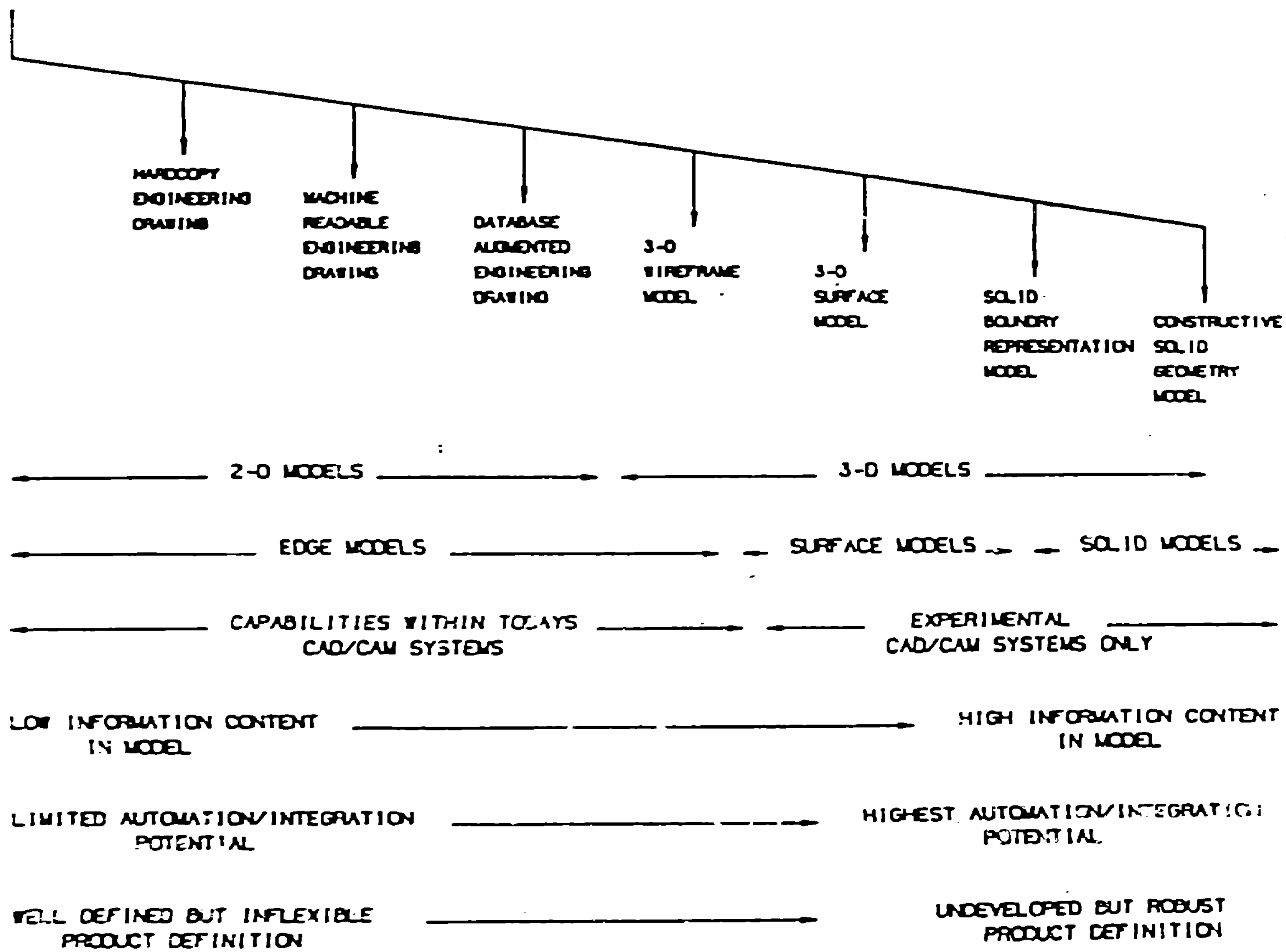


Figure 16